9/22/23.

KARNAK BULLETIN NO. 5

ROOFING MATERIALS

A. I. A. STANDARD CLASSIFICATION

FILE NO. 12-B-1

KARNAK

TRADE MARK

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FOREWORD

Existing standards for the great majority of basic materials of construction are simply the results of the wide and general experience of the construction profession, which experience has been crystallized and expressed in concise and definite form through the work of our technical societies and associations.

As a means of determining quality as fixed by these standards, these same societies and associations have set up a series of tests (which also have become standard), sometimes arbitrary in character but always carefully designed to fix the character and quality of the material tested.

No generally accepted standards of quality exist at present for roofing materials, and real specifications for roofing are seldom seen. It is a fact, however, that the American Society for Testing Materials, the American Society of Civil Engineers, and others of our technical societies, cooperating with the United States Bureau of Standards, have standardized a series of tests for bituminous materials, which tests will predetermine with reasonable accuracy just how these materials will behave in service and what life may reasonably be anticipated from them.

This is the most important single fact connected with the roofing industry and is one that is seldom if ever recognized by those who are specifying or purchasing roofing materials.

It is, however, recognized by the Federal Government, by every State in the Union, by every county and by every city, all of which determine the quality of the bituminous materials purchased by them, not by trade name but by use of these standard tests which are incorporated in their specifications. It cannot be maintained, of course, either that these governments are acting in ignorance or that they consistently obtain poor materials.

The fact that the suitability of any material offered for roofing can be so readily and so definitely determined carries to the architect and engineer two messages of great value and importance.

1. Roofing materials can be taken out of the realm of uncertainty and placed on a plane of definiteness and certainty; reliance on meaningless trade names and facile guarantees can be done away with and the use of roofing materials placed on the same intelligent basis as cement, steel and other structural materials.
2. Practice can keep pace with progress and full advantage be taken of improvement in material without waiting for a service record of many years to establish such improvement. This will obviate utter and complete stagnation in an important material of construction.

This bulletin is devoted to a discussion of roofing materials from the viewpoint of these standard tests in an effort to give correct, definite and precise data on which intelligent judgment may be based.

CRITERION

Before entering into a discussion of the various materials that are being offered for roofing work, we may lay down a fundamental principle underlying a successful waterproofing material:

> *Wherever waterproofing is to be used under conditions such that it can be readily influenced by atmospheric temperature, it should be, in its physical properties, as little affected by fluctuations in temperature as is consistent with permanence and complete stability.*

In other words, the first consideration is permanence. That can neither be sacrificed nor compromised. After that, however, the material should neither be excessively brittle nor excessively soft at the extremes of temperature to which it is sure to be subjected. The only type of bituminous product that fills this requisite is found among the asphalts.

ASPHALTS

No judgment of value, however, can be passed on asphalts as a class for any use or purpose, as the term asphalt is generic and covers a multitude of products. Opinion is valuable only as it refers to a particular asphalt in connection with a particular use. An asphalt, for example, that might function most satisfactorily as a paving asphalt by reason of the constant kneading of traffic might very well fail dismally as a roofing or waterproofing material where the kneading is absent. This discussion therefore will be limited to the particular asphalts that are being marketed today as roofing materials.

Such asphalts may for purposes of discussion be classified into the following groups, based on the representations of the various manufacturers: fluxed asphalts; lake asphalts; unfluxed asphalts refined from asphaltic petroleum.

FLUXED ASPHALTS

Fluxed asphalts are compounds or mixtures made by adding either a soft asphalt or an oil to a hard asphalt to reduce it to a proper consistency. The use of such a material, whether compounded with the hard asphalts of the Gilsonite class, or with refined semi-solids such as the Trinidad or Bermudez, is always attended with danger, as it is extremely difficult to determine, even by chemical examination, whether the combination between the flux and the hard asphalt is a permanent one. Some fluxes will combine with a particular base and give lasting results; some will not. Where the flux is not suitable, the compound deteriorates rapidly and becomes "cheesy", free oil is liberated and is absorbed by the concrete or evaporates, leaving behind, eventually, a hard, brittle asphalt. A fluxed asphalt therefore while not necessarily faulty is at least always open to suspicion as to its permanence.

LAKE ASPHALTS

This term is used to describe those asphalts which are obtained from Bermudez and Trinidad Lakes.

Neither of these asphalts can be used in their crude state; both require to be refined by the application of heat under proper regulation. And it is an important fact that in this process approximately 33 per cent by weight of Trinidad and nearly 40 per cent of Bermudez, in the form of water and light oils is driven off the crude materials.

In both of these products, however, the change which has been effected by nature in the character of the original petroleum from which they are derived has progressed so far that the refining cannot vary the character of the final product materially without destroying or greatly injuring it. In their refined state, therefore, they are entirely too hard for roofing work (as evidenced by the analyses shown later) and have to be softened by the use of a flux or softening agent. This immediately brings them in the class of fluxed asphalts, which for reasons stated under that heading are at best of uncertain life and behavior.

It is claimed for these products that exposure to the tropical sun for years has produced a stable and unchangeable material. This is disproved by the following facts:

a. Water has a rapidly destructive effect on Trinidad asphalt.

b. There is a very appreciable quantity of light oils in both which have not been stabilized (4 per cent in Trinidad and 11 per cent in Bermudez).

c. Since the asphalt in Trinidad Lake is in constant movement, the time of exposure of any particular lot is small. As to Bermudez, everything would indicate that the Bermudez deposit is of recent origin and has not been exposed for ages to the tropical sun.

d. Under the standard heat test (see page 9) their lack of stability is indicated by their hardening, Trinidad and Bermudez both hardening more than 30 per cent.

Even if true the claim as to unchangeability by reason of tropical exposure would not apply to the roofing asphalts made from lake asphalts because, as has been stated, they are always compounded with oils or softer asphalts from other sources to reduce them to a proper consistency; so that the stability of the base is not a gauge of the stability of the finished product.

UNFLUXED REFINED ASPHALTS

This caption comprises those asphalts which have been refined from

liquid bases: the so-called malthas or the heavy asphaltic petroleums. Asphalts from such bases can, by proper methods of refining, be made into

a. Thoroughly stable products, both physically and chemically.

b. Products which will have the desired physical properties.

Just what properties are desirable the engineer or architect readily appreciates; but how can he, unless he be an authority on bituminous materials or consults such authority, form any opinion as to the life or wearing qualities of a material having these physical properties? To this there is but one answer. If he does not consult an authority on bituminous products, he must place dependence on the experience of the constructing profession with the particular type of material which embodies the nearest approximation to the desired properties.

The physical properties desired in a satisfactory roofing material are almost self-evident. These may be summarized as follows:

1. Since the material is directly exposed to the weather it should be as little affected by temperature changes as possible; that is, it should not be so brittle at low temperatures that it can be readily fractured, nor should it be so soft at high temperatures that it will flow or seep from inclined surfaces. To express this in terms of standard bituminous tests, the difference between the penetrations measured at 32° F. and 115° F. should be a minimum.

2. The ductility of the material, or its capacity to stretch, should be a maximum; the higher the ductility the stronger the adhesion to the slab and the greater the ability to yield without fracture to any change in the surfaces covered.

Fortunately for the structural profession, an asphalt of this type has been in use for many years for waterproofing a form of structure entirely analogous to a roof. That is, on a flat slab bridge floor. Moreover, such a type of asphalt has been used in direct comparison with other materials widely advocated for roofing purposes so that *relative* efficiency and permanence have been clearly established.

As has been stated, waterproofing a bridge floor is structurally a problem very similar to waterproofing a roof slab. If the roof is to be covered with tile, the structural conditions become identical. A bridge floor is subjected of course to certain conditions not found in a roof, such as shock of impact, a certain measure of vibration (particularly in steel bridges), a certain deflection. But these are conditions of service, not structural conditions. If, therefore, a certain type of material has been found to give superior

service on a bridge floor, the service that can be anticipated on a roof where conditions are less rigorous and exacting is even greater.

The table shown on the next page illustrates to a very limited extent the *frequency* of the appearance of a specification calling for this type of asphalt; and it may be noted that in the field of bridge waterproofing it has practically become a standard.

A proper understanding of the table shown and of the specification which will be suggested, requires an understanding of the tests, previously referred to, which have been adopted as standard by the American Society for Testing Materials and the American Society of Civil Engineers. These tests are:

1. The softening point.
2. The penetration at 32° F., at 77° and at 115°. These show the depth (measured in hundredths of a centimeter) to which a weighted needle acting for a given time will penetrate the material. This test is therefore a measure of the consistency of the material, that is its relative hardness or softness, at the temperatures mentioned.
3. Ductility at 40° and at 77° F. These measure the stretch of the material at the two temperatures. The ductility at 77° F. is important as giving the best gauge of the adhesion of the material to masonry, and under a particular circumstance, of the life of the material. That circumstance is this: Roofing asphalts are refined in part or in whole by what is known as the "blowing" or oxidizing process. This process, properly conducted, can produce a most efficient material. At the same time it is a dangerous one because of the possibility of over-oxidizing the material; and an over-oxidized asphalt will soon lose its life and become "cheesey." The most infallible test of this is the ductility since, as far as is known, it is impossible to over-oxidize an asphalt and at the same time keep the ductility up.
4. Durability test. This test is made by heating the material at 325° F. for 5 hours and measuring the percentage of loss in weight and the percentage of hardening. This is an accelerated service test; the greater the loss in weight and the percentage of hardening, the less serviceable the material will be.
5. The percentage of the material soluble in cold carbon disulphide. This shows the purity of the product and, as the bitumen content alone has waterproofing value, the amount of the waterproofing agent in the material.

All of these tests should be applied. They form a composite whole and the omission of any one of them would make it impossible to draw definite conclusions based on the other four.

ASPHALT SPECIFICATIONS

		Penetration		Ductility		% of Purity	Durability		M. P. (R & B)	Specif. Grav.	Architect or Engineer
		32°F.	115° F.	40°F.	77°F.		% Loss in Wt.	% Loss in Pen.			
							Thru Htg. at 325° F. for 5 Hours				
D. L. & W. R. R.......	Min.	10		4	12	99			150	1.0	Geo. J. Ray,
	Max.		100				½	20	180		Chief Engineer
Trenton, N. J. Bridge.	Min.	10		4	12	99			150	1.0	J. A. L. Waddell & Son
(Mercer Co., N. J.)	Max.		100				½	20	180		
C. B. & Q. R. R.......	Min.	10		3	15	99			150	1.0	G. A. Haggander,
	Max.		100				½	10	175		Eng. of Bridges
P. & R. R. R..........	Min.	10		3	15	99			150	1.0	S. T. Wagner,
	Max.		100				1	20	180		Chief Engineer
Troy-Cohoes Bridge...	Min.	10		3	15	99			150	1.0	State of N. Y.
(State of N. Y.)	Max.		100				½	20	180		
American Concrete...	Min.	11		3	15	98					Committee S-2,
Inst. (Tentative)...	Max.		100				1	25			Amer. Conc. Inst.
Chicago Union Station	Min.	10		3	20	95			150		J. D'Esposito,
Co. (Bridges)......	Max.		90				1		180		Chief Engineer
Cedar St. Bridge	Min.	10	75	3	20	99½			150	1.0	M. S. Grytbok,
(City of St. Paul)	Max.		100				½	10	170		City Eng. of Bdges.
Military Ave. Bridge.	Min.	10	75	3	20	99½			150	1.0	C.W.Hubbell,CityEng.
(City of Detroit)	Max.		100				½	10	170		J.W.Reid,Eng.Gr.Sep.
N. Y. Co. Court House	Min.	10	75	3	20	99½			150	1.0	Guy Lowell,
(Roof&SidewalkSlabs)	Max.		100				½	10	170		Arch.
Chicago & N. W. R. R.	Min.	10	75	3	20	99½			150	1.0	J. S. Pole,
	Max.		100				½	10	170		Eng. Track Eleva.
N. Y. C. R. R.........	Min.	10	75	3	20	99½			150	1.0	H. T. Welty,
(Lines E. of Buffalo)	Max.		100				½	10	170		Eng. of Struct.
N. Y. C. R. R.........	Min.	10	75	3	20	99½			150	1.0	B. R. Leffler,
(Lines W. of Buffalo)	Max.		100				½	10	170		Eng. of Bridges
W. 73rd St. Bridge....	Min.	10	75	3	20	99½			150	1.0	F. R. Lander,
Cleveland, Ohio	Max.		100				½	10	170		Co. Engineer
Neb'ska State Capitol.	Min.	10	75	3	20	99½			150	1.0	Bertram G. Goodhue,
WaterproofingTerraces	Max.		100				½	10	170		Arch.
Karnak..............	Min.	10	75	3	20	99½			150	1.0	....
	Max.		100				½	10	170		

TWO-PLY ASPHALT SATURATED COTTON FABRIC SPECIFIED IN EACH CASE

As bearing directly on this subject the following extracts from the 1922 report of Committee S-2 on Reinforced Concrete Highway Bridges and Culverts, American Concrete Institute, are pertinent.

*"The American Society for Testing Materials and the American Society of Civil Engineers have established standard tests for bituminous materials and have described in minute detail how such tests shall be made. From these tests it is entirely possible to predetermine with considerable accuracy how bituminous materials will behave in service and the relative life that may reasonably be anticipated from them. Therefore, reliance should not be placed on trade contentions of a material of inexplicable composition. Through lack of proper investigation the profession has been badly misled. Specifications can and, in the opinion of your committee, should be written which describe by standard tests previously mentioned the quality of the material desired just as the quality of the aggregates, cement, steel and other materials is described.

(1) The asphalt used should have the highest possible percentage of bitumen, as the bitumen content in an asphalt is the waterproofing content of value. Many asphalts will test 99½ per cent pure—98 per cent would not be an unreasonable requirement.

(2) The asphalt should be relatively soft at 32 deg. F. and relatively stiff at 115 deg. F. In other words the ratio between the consistencies of the material at these temperatures as measured by the standard penetration tests, or the "susceptibility ratio," should not be greater than 9 with a maximum penetration (standard test) at 115 deg. F. of one centimeter.

(3) The ductility at 77 deg. F. should be not less than 15 cm. and should be as great as possible. There are several reasons for this. An asphalt with a low "susceptibility ratio" can be produced, as has been ascertained, by the oxidizing process only. This process must be conducted with great care since, if an asphalt is over oxidized it may for a short period after being manufactured, appear to exhibit the required properties, but be subject thereafter to a rapid disintegration which changes it into a "cheesy" substance entirely devoid of waterproofing value. It is not believed possible to over oxidize an asphalt and still retain the minimum ductility mentioned. Adhesion to the concrete and to the membrane is undoubtedly of great importance; since the ductility is perhaps the best gage of the adhesive value of the material, it should be as high as possible consistent with the penetration requirements. This statement is applicable regardless of temperature, but it is even more important at low temperature than at high; a ductility of at least 3 cm. at 40 deg. F. is desirable.

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(4) The losses in weight and in penetration through heating for five hours at 325 deg. F. should be a minimum—not more than 1 per cent and 25 per cent respectively. This test is an accelerated ageing test and is intended to insure the durability of an asphalt. The desirability, therefore, of a material undergoing a minimum change when subjected to it is manifest.

From a waterproofing standpoint these tests, it is believed, comprise all the important tests prescribed by the two organizations mentioned, but it is to be noted that they have a significance only when construed together,— that no correct conclusion can be drawn from any one or from several of them unless all are included."

The following table shows typical analyses of Coal Tar Pitch and Karnak Asphalt contrasted with the requirements of the American Concrete Institute's Tentative Specification

	Penetration		Ductility		% of Bitumen	Weight Loss thru Heating	Penetration Loss
	32°	115°	40°	77°			
Amer. Conc. Inst. Tent. Spec.	11+	100−	3+	15+	98	1%	25%
Coal Tar	3	175	0	100	74.5	1.8%	43%
Karnak	12	90	4	32	99.9	.02%	9%

KARNAK ASPHALT

Karnak asphalt is produced from a very heavy Mexican crude asphaltic petroleum, containing 97 per cent of bitumen in the crude state. It is first purified, and then refined by thoroughly well-understood and entirely standardized processes. The distinguishing feature, however, is that these processes are kept under the most exact control in order that the character of the finished product may be assured. It is entirely an unfluxed product, no additions of any kind being made at any stage of the refining processes. A complete specification is given on pages 14 and 15.

Reference to the following tables will illustrate many of the points brought out in the preceding pages.

TABLE I

This table shows a comparison of coal tar pitch with Karnak asphalt. Stock samples of both materials were tested by the same authority.

	M. P. ° F.	Penetration at 32° F.	Penetration at 77° F.	Penetration at 115° F.	Ductility at 40° F.	Ductility at 77° F.	Durability % Loss in wt.	Durability % of hardening	% Soluble in CS_2
Coal Tar Pitch	132	3	14	175	*	100+cm.	1.8	43	74.05
Karnak	155	12	28	90	4 cm.	32 cm.	.02	9	99.9

* Too brittle to test.

From this table it is seen that coal tar pitch is exceedingly brittle at 32° and exceedingly fluid at 115° F. The low percentage of bitumen and the relatively high percentage of loss in weight and in penetration after being subjected to the heat test are noticeable.

TABLE II

This table shows a comparison of Trinidad and refined Bermudez asphalts with Karnak asphalt.

	Penetration at 32° F.	Penetration at 77° F.	Penetration at 115° F.	Ductility at 77° F.	Durability % Loss in wt.	Durability % of hardening	% Soluble in CS_2
Trinidad	0	2	12	*	0.6	30	56
Bermudez	5	21	133	27 cm.	0.8	29	96
Karnak	12	28	90	32 cm.	.02	9	99.9

This brief discussion of bituminous materials may well close with a few cautionary statements to the structural profession—architects and engineers.

a. Write a specification so that it requires a certain quality of material as determined by standard tests—not *any* quality marketed under a self-assumed name.

b. Be sure that you have *all* the tests and not merely those a manufacturer may give you; for unless you have all, you had better have none.

c. Do not use a material merely because it is soft at 32° and stiff at 115°. Unless such a material has a ductility at 77° of 20 or over, it will be lacking in adhesion and very probably in length of life.

d. Do not use any material no matter who makes or sells it without an independent test made on a sample of material taken from an actual shipment.

e. When you get the test, reject the material if

   1. The ductility is less than 20 regardless of the penetrations.
   2. The loss in weight due to heating is greater than 1 per cent.
   3. The loss in penetration due to heating exceeds 15 per cent.
   4. The ratio between the penetrations at 32° and 115° exceeds 1 to 9 with a maximum at the latter temperature of 100 — Standard test.

f. Do not expose the bitumen to the sun without a shield of gravel, asbestos felt, or other similar material. To do so is more dangerous

* Too brittle to test.

with coal tar pitch (because of its higher volatility) than with asphalt, but in neither case is it safe practice.

THE MEMBRANE

The membrane in a roofing blanket has a function hardly secondary to that of the asphalt. It has no true waterproofing value as such, any more than expanded metal adds any true strength to a concrete slab. In fact the function of the membrane in a roofing blanket is precisely the same as that of expanded metal in concrete, i. e., to hold the surrounding material in place, to prevent it from cracking up.

The selection of the proper type of membrane can be made only as a result of an engineering determination of the structural conditions to which the material is to be subjected in service, and of the stresses these conditions create in the blanket.

I Of primary importance of course is the requisite that the membrane be unaffected by water. Even though the membrane exists only as a binder with no waterproofing value *per se,* it is elemental that the membrane should be permanent under service conditions, and that it should remain effective even though water may reach it directly. To be compelled to waterproof the waterproofing is to approach the ridiculous.

II The membrane should be elastic. The base to which the roofing is applied is not a fixed area. On the contrary, it is an area which is constantly changing with atmospheric temperatures. In other words the distance between any two points on the roof increases or decreases with corresponding temperature changes. Moreover, as the roof slab is thin, the reaction to temperature variation is relatively rapid. This change in surface area creates heavy tensile stresses in the roofing blanket. The blanket must then yield or rupture.

Again, it is difficult, regardless of any reinforcement, to build a flat slab which will not develop cracks. It is impossible to build one that we *know* will not crack. Here again we have, but from another cause, an increase in the area which the roofing blanket covers, and here again we have the same alternatives—it must yield or rupture.

III The membrane should have a certain measure of strength. A good roofing bitumen has a very positive adhesion to any form of roof base. It also naturally adheres strongly to the membrane. If any increase in the waterproofed area occurs, by the formation of cracks or otherwise, stresses are created in the entire blanket; and

if these stresses are localized, the blanket will rupture. The membrane therefore must be strong enough to distribute these stresses through the bitumen, a material distance on either side of the crack and thus prevent this localization. In this way the stretch in a considerable length of the membrane will be brought into play. This may be briefly though inexactly expressed by stating that the strength of the membrane must be greater than that of the bitumen.

IV The membrane should have an open mesh or (to put it another way) should be sufficiently porous to allow for free penetration of the waterproofing material proper, i. e., the asphalt or the coal tar pitch. The function of the membrane, it must be remembered, is to reinforce the waterproofing—to hold it in place and prevent it from breaking or cracking. In this particular its use is entirely analogous to the use of expanded metal in a concrete plate. Therefore, just as the mesh of the metal permits the concrete to pass through and interlock with itself, so should the waterproofing pass through the membrane.

Again, if we specify a given thickness of material, as we do when we require a given number of pounds or gallons to be used in waterproofing a given area, we want the waterproofing value of that thickness as a whole, not the value of a number of thin films that aggregate that thickness. If we create these films by dividing the required thickness with layers of a material that the waterproofing does not penetrate, the resulting efficiency is measured by the efficiency of each individual film and not by the total thickness at all. It is just as if we attempted to build a beam by laying a series of boards one on top of another. They function independently and have the strength only of one single board. We obtain a beam with the combined strength of all, only when we fasten them together.

V The roofing blanket should conform closely to the surface to which it is applied, following strictly all surface irregularities and fitting snugly into all corners where it changes direction. In other words it should have solid backing everywhere with a complete absence of unsupported spans or "bridges" which will break down if subjected to traffic.

This demands a high degree of flexibility.

VI The treated membrane should be without capillary properties and should facilitate such an intimate welding together of the successive moppings that lateral translation of water through the blanket is impossible.

The following table presents an analysis of the various membranes on the market.

Type of Membrane	Composition	Effect of Water on	Elastic Properties	Tensile Strength	Flexibility	Capillarity
Asbestos Felt... (Saturated)	Asbestos fibre tied together with tapioca or starch and run through a bath of liquefied asphalt and resin.	The fibre itself will be unaffected; but the felt is liable to disintegrate because both starch and tapioca are soluble in water.	None	Weakest of all felts.	Rather brittle. Liable to break if bent over sharp corner.	None
Rag Felts....... (Saturated)	Composed of cotton rags and wood pulp. First treated with creosote to prevent dry rot, then put through a bath of liquefied asphalt or coal tar pitch.	When immersed softens very materially and gradually melts.	None	Very weak but somewhat stronger than asbestos felt.	Same as asbestos felt.	Have very appreciable capillary properties.
Burlap or Jute.. (Saturated)	A harsh woody fibre impossible to impregnate completely with a viscous material. Is first treated with thin asphalt or coal tar cut back, and then coated with asphalt or coal tar.	Rapidly destroyed particularly if water carries alkali—very unstable chemically. Will be rotted even by moisture in the air.	Practically none.	Considerable when fresh but quickly dissipates with age.	Flexible when new but becomes brittle with age.	Very highly capillary and hygroscopic. These properties but little decreased by saturating treatment.
Cotton Cloth... (Saturated)	A pure cellulose chemically stable Can be thoroughly impregnated with asphalt without the aid of solvents.	Entirely unaffected by water if completely saturated.	Excellent if proper base fabric is selected.	Any strength desired.	Extremely flexible at all temperatures. Does not deteriorate with age.	Absolutely without capillary properties and non-hygroscopic.

A brief examination of this table will show that of all the membranes, a properly saturated cotton fabric alone fills the structural requirements. Nor is this mere theory. The experience of the past ten years has demonstrated conclusively that the theory is not only sound but is entirely correct in practice.

Ten years ago, all of the consulting engineers engaged in bridge work and all of the railroads, used as a membrane in their waterproofing five or more plies of either rag or asbestos felt. Gradually this method has been given up—one by one they have substituted two plies of cotton cloth

for the multiple plies of the weaker felt until today practically all of the engineers whose work is with bridges are using a cloth system. Their experience has demonstrated beyond question that two cardinal principles underlie all successful waterproofing, viz:

1. If a film of material is truly waterproof it cannot be made more so by piling up additional films. The results are a function of the quality of material and the perfection of its application rather than of its mass.
2. As a corollary of the first, results depend on a high quality material held in place by a strong, elastic binder, which binder is itself guarded by a film of the same material above and below it.

Karnak Roofing Cloth is a good grade of cotton cloth which has been thoroughly impregnated with Karnak Roofing Asphalt. While the *quality* of the cloth is the same as Karnak Waterproofing Fabric, the cloth is lighter and hence is not as strong. The difference is frankly made for economic reasons. Engineering or architecture is a problem in economics as well as in construction. From the standpoint of economics it consists in the selection of the cheapest materials available that will fully and adequately meet a given need.

A waterproofing fabric on flat slab bridges is subjected to stresses not found in a fabric placed on a roof. On a bridge floor it is called on to function with the weight of the paving holding it down. It is subjected to greater or less vibration, to shock of impact. These rigorous conditions do not apply to a roofing material, and as the stresses are not so great, a weaker material can be used, in fact should be used, without in the slightest degree reducing the factor of safety. A specification for Karnak Roofing Cloth appears in the latter pages of this bulletin.

PROTECTION AGAINST EXPOSURE

The effect on bituminous materials of exposure to the sunlight has already been mentioned. To obtain a maximum of life from the material used it should be protected against such exposure.

No comment is needed as to the use of slag or gravel for this purpose. The use of asbestos felt is recommended because the asbestos fibre is practically indestructible—being a stable mineral—and is entirely without capillary properties. The asphalt into which it is embedded, having high ductility, possesses great adhesive properties, so that the felt is thoroughly and firmly tied into the roofing. This cap sheet is not called upon to exercise any waterproofing function. It is placed merely as a shield—nothing more. Its friability is therefore a matter of no moment.

It is recommended that if asbestos felt is used it be given a heavy coat of a good asphalt-asbestos paint for the purpose of sealing any pores that may exist in the felt sheet.

Complete specifications for materials follow. It is to be noted that these make for a true specification roof in the sense that they require a certain quality of material be furnished, not merely that *any* quality be applied in a certain way. The importance of this lies in the fact that while the best material may suffer from improper application, no amount of care or expertness in the application will cure the defects inherent in an inferior material.

The specifications given also suggest a method by which, with minimum trouble, compliance with the specifications may be insured.

SPECIFICATIONS FOR ROOFING MATERIALS

1. The roofing shall be built up of two layers or plies of an asphalt saturated cotton fabric and three moppings of roofing asphalt. Into the final mopping there shall be imbedded a layer of asphalt saturated asbestos felt, the exposed surface of which shall be given a heavy coat of an approved asphalt-asbestos paint.

The materials used shall comply with the following requirements:

ROOFING FABRIC

2. The roofing fabric shall be a cotton fabric which before being delivered on the work shall have been thoroughly saturated with the asphalt specified below and of the same brand of manufacture as that with which the fabric is to be applied.

The finished fabric shall have a tensile strength both in the warp and in the filling of not less than 35 pounds per inch of width and a stretch in both directions of not less than 6 per cent.

ROOFING ASPHALT

3. The roofing asphalt shall be free from coal tar pitch or any of its products, and shall contain not less than 99½ per cent of bitumen soluble in cold carbon disulphide.

It shall have the following properties, which properties shall result solely from the process of refining whatever crude material is used, without the addition of any fluxing or other material during any stage of the refining process:

a. A softening point of between 150° and 170° F., Ring and Ball method. (A.S.T.M. D36.)

b. A penetration at 32° F. of not less than 10; at 115° F. of between 75 and 100. (A.S.T.M. D5.)

c. A ductility at 77° F. of not less than 20 centimeters, the material being elongated at the rate of 5 centimeters per minute; and at 40° F. of not less than 3 centimeters, the rate of elongation being not over 1 centimeter per minute. (A.S.T.M. D113-21T.)

d. When 50 grams of the material are heated for 5 hours at 325° F. in a tin box 2½ inches in diameter, it shall not lose over 0.5 per cent by weight, nor shall the penetration at 77° F. after such heating be less than 90 per cent of the original penetration at that temperature. (A.S.T.M. D6.)

ASBESTOS FELT

4. The asbestos felt shall be of good grade, thoroughly saturated, and shall be equal to that known as a 14-pound felt.

ASBESTOS ASPHALT PAINT

5. The asphalt-asbestos paint shall be made from a Mexican base asphalt thinned with a suitable solvent derived from the same crude as the asphalt. Into it shall have been incorporated sufficient asbestos to give a heavy liquid of such consistency as to flow freely under the brush, but to leave a thick protective coating on the felt.

6. All materials shall be delivered in their original packages, plainly marked with the manufacturer's brand or label.

TEST

The architect shall take from each shipment of material a sample which shall be tested, at the expense of the manufacturer by an independent authority. Should the material not comply with the specifications the manufacturer shall immediately remove it from the work.

KARNAK

UNALTERABLE PRODUCTS

KARNAK SPECIALTIES

WATERPROOFING FABRIC

WATERPROOFING ASPHALT

ROOFING FABRIC

ROOFING ASPHALT

LIQUID DAMP-PROOFING

TROWEL PLASTIC

BRUSH PLASTIC

STONE BACKING

STRUCTURAL STEEL COATING

EXPANSION JOINT CEMENT (S)

EXPANSION JOINT CEMENT (H)

CAULKING ROPE